IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of.:			
	Irad BEN-GAL et al		
Serial No.:	10/076,620		
Filed:	February 19, 2002	Group Art Unit:	2123
For:	STOCHASTIC MODELING OF TIME DISTRIBUTED...		
		Attorney Docket:	01/21716
Examiner:	Ayal I. Sharon		

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION UNDER 37 CFR 1.132

Sir:

We, Irad Ben-Gal of 12 6/12 Simtat HaDror Street, Herzlia, Israel; Armin Shmilovici of 13 Harkabi Street, Tel-Aviv, Israel; Gail Morag of 14 Rambam Street, Herzlia, Israel; and Gonen Zinger of 19 Jacob Dori Street, Hadera, Israel declare as follows:

1. That the inventors of the invention disclosed and claimed in the above-identified application are:

a) Irad Ben-Gal of 12 6/12 Simtat HaDror Street, Herzlia, Israel

b) Armin Shmilovici of 13 Harkabi Street, Tel-Aviv, Israel

c) Gail Morag of 14 Rambam Street, Herzlia, Israel, and

d) Gonen Zinger of 19 Jacob Dori Street, Hadera, Israel;

2. That Irad Ben Gal, Armin Shmilovici, Gonen Zinger and Gail Morag were the researchers of the CONSIST Consortium, which was supported by the Chief Scientist office of the Ministry of Industry, Trade and Labor of the State

of Israel. The invention claimed in the above-identified application is largely a result of the research performed by the named inventors under the aegis of the CONSIST Consortium.

3. That Irad Ben Gal, Armin Shmilovici, and Gail Morag were co-authors of an article entitled *An Information Theoretic Approach for Adaptive Monitoring of Processes*, presented at ASI2000, The Annual Conf. of ICIMS-NOE and IIMB. 2000; and

4. That co-inventor, Gonen Zinger, was a contributor to the research described in the above-identified publication. His name was omitted from the list of authors due only to the fact that he did not actively participate in the writing of the article.

In evidence of the above statements, we hereby enclose the following Attachments:

Attachment A) "Diagnostics of Production Runs Anomalies through Context Identification" dated October 30, 1999: The proposal submitted by Irad Ben Gal and Armin Shmilovici to the Chief Scientist of the Ministry of Industry, Trade and Labor of the State of Israel in order to obtain funding for the CONSIST Consortium. In the proposal they state that two Master's students from Tel-Aviv University (TAU) will be part of the research team.

Attachment B) Email correspondence dated May 23, 2000, between Dr. Irad Ben Gal and Oshrat Cohen of the Ramot Projects Department, discussing budgetary constraints for the employment by the CONISIST Consortium of Gonen Zinger and Gail Morag (who are the two Masters's students selected as per the above proposal), in which the employment of Gonen Zinger is discussed and approved.

Attachment C) An English translation of a timesheet dated October 10, 2000, which was provided by Dr. Irad Ben Gal to the Project Management Department of Tel Aviv University to report the monthly hours worked by

Gonen Zinger and Gail Morag for the CONSIST Consortium, during the months of January 2000 through September 2000.

Attachment D) "Diagnostics of Production Runs Anomalies through Context Identification: Work plan for research assistants", dated July 28, 1999: The work plan clearly identifies research assistants Gail Morag and Gonen Zinger.

The results of several items allotted to Gonen Zinger are specifically disclosed in the publication entitled *An Information Theoretic Approach for Adaptive Monitoring of Processes*. These items include:

- Construction of a context tree from a given sequence – see the fourth column of the above-identified publication;
- Determining the optimal number of levels (q) by joining/splitting of tree – see the fourth column of the above-identified publication; and
- Implementation of known statistical methods – see the usage of Kullback-Leibler (KL) statistic measure in the above-identified publication.

Attachment E) An English translation of a letter dated January 16, 1999 from Dr. Irad Ben Gal to the IDF (Israel Defense Forces), stating that Gonen Zinger is participating in a research project in the area of Statistical Process Control (SPC). This participation contributed to the research described in the publication entitled *An Information Theoretic Approach for Adaptive Monitoring of Processes*.

Attachment F) Email correspondence between Dr. Irad Ben Gal and Mr. Ludek Sztefek which includes an abstract of a paper submitted by Gonen Zinger and Dr. Irad Ben Gal to the ICPR-16 Conference, which took place in Prague, Czech Republic on 29 July - 3 August 2001, and is identified as being the work of Zinger. The title of the paper is "A Methodology for Integrating Engineering Process Control and Statistical Process Control", and it concerns the use of context tree models for statistical process control. The work presented in this

paper contributed to the research described in the publication entitled *An Information Theoretic Approach for Adaptive Monitoring of Processes*.

Attachment G) The title page and summary of the thesis submitted by Gonen Zinger under the supervision of Dr. Irad Ben Gal to the Department of Industrial Engineering at Tel Aviv University. The thesis is entitled "Application of Statistical Process Control to Feedback-Controlled Systems via Context Modeling", and includes research which contributed to the publication entitled *An Information Theoretic Approach for Adaptive Monitoring of Processes.*

Please note that in Attachments D, F and G, Gonen Zinger's name is spelled as "Gonen Singer". Both spellings refer to a single individual, an inventor of the invention disclosed and claimed in the above-identified application.

Attachments C and E will be provided in the original Hebrew if requested by the Examiner.

Applicants respectfully urge that the enclosed documents show that inventors Irad Ben Gal, Armin Shmilovici, Gonen Zinger and Gail Morag collaborated prior to September 18, 2000 on the research which resulted in the submission of the above-identified application.

We declare that all statements made herein of our knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that willfully false statements are punishable by fine or imprisonment under 18 U.S.C. Section 1001 and that any such statement may jeopardize the validity of the subject application or any patent issued thereon.

Irad Ben-Gal

Dr. Irad Ben-Gal

Date: September 4, 2007

Dr. Armin Shmilovici

Date: September 4, 2007

B/Gail Morag

Gail Morag

Date: September 4, 2007

Gonen Zinger

Date: September 4, 2007

Dr. Irad Ben-Gal	Date: September 4, 2007
Armin Shmilovici Dr. Armin Shmilovici	Date: September 4, 2007
Gail Morag	Date: September 4, 2007
Gonen Zinger	Date: September 4, 2007

Attachment A

30.10.1999

Research Proposal: Diagnostics of Production Runs Anomalies through Context Identification.

Submitted by:
Dr. Shmilovici, Ben-Gurion University
Dr. Ben-Gal, Tel-Aviv University

Summary

Modem production lines are complex real-time systems, thus, any faults are expected to be detected and signaled as soon as possible. Unfortunately, since most fault generating processes are not well understood, most faults can be corrected only after they happen.

The purpose of this project is to develop several applied diagnostic algorithms which can assist in tracing the cause of various types of production runs anomalies. It is expected that, when a production system will be diagnosed as entering a fault generating process, a corrective action could be initiated even before any actual defective product will be produced.

The project will use the CONSIST consortium's object model as its underlying system description tool, making the developed algorithms accessible to a wide variety of uses. It will contribute to CONSIST by enabling users of the CONSIST framework to operate their production lines at higher efficiencies, and to use intelligent feedback in designing new or modified production lines. In that way, it adds to the value proposition of CONSIST tools and technologies.

Project Goals

Current situation:

One important challenge of designing and operating production lines is the issue of reliability. Reliability problems can manifest as unscheduled down time due to faults. They can also manifest as decreasing yield – increasing number of problems in the manufactured products. These problems may be detected during production, at the end of the production line, or even on delivery to customer, resulting in rejects and/or rework. Reliability problems lead to lower productivity and higher costs. With today's shift to higher quality standards (where faults are often measured in parts per million), planning for high reliability is receiving strong attention.

During production, it is important to identify problems as soon as possible. This not only cuts down on problems in the manufactured products: it is often the case that a problem detected quickly can be solved faster and cheaper than the same problem detected later.

In today's production line operation, this issue is addressed in two ways:

A. Monitoring production line status as reported by sensors and production cell hardware: These reports are automatically gathered, logged and analyzed, with alarms set for threshold values or dangerous trends. These alarms are set by humans according to their understanding of the production line. However, production line are complex, dynamic systems, and their behavioral parameters

vary over time and vary with their specific tasks at each moment. Therefore, the automatic alarms only detect expected, discrete fault situations. Many problems, including "soft" problems leading to defects down the line, will not be detected.

B. Periodic evaluation of end-of-production-line problems using SPC (Statistical Process Monitoring) and Pareto or "fishbone" techniques. These methods can direct the manager's attention towards specific problem symptoms, but do not include any way to map the product problem to specific production line faults causing this problem. Additionally, since the cause analysis cannot be automated without a strong model linking product elements to production resources and actions, it will usually take some time before the engineers identify and then fix the problem.

In today's production line design, reliability is usually not handled in any structured, methodical way apart from the common technique is evaluating MTBF. This technique answers the question of how often specific elements, cells or complete production lines can be expected to fail, but does not report how easy would it be to detect, and then diagnose, the problem.

Proposed solution:

Adding more intelligent monitoring analysis will be able to identify subtle anomalies in combinations of measurements from many sources. Such analysis will be able to identify problems on a much finer resolution than the resolution achievable with manually set alarm triggers, leading to detecting more problems, and earlier, than possible before.

Linking the monitoring analysis to real-time product fault reports (e.g. from end-of-production-line testing) will be able to match even small changes in the frequency of specific types of faults to small variations of observed operational parameters; not only identifying that a problem exists, but also pointing out the specific indicator (and therefore, specific production element) associated with the problem.

Linking to the consortium's production line model:

1. Linking product features to production line resources and activities
2. Linking sensors and indicators to production line elements
3. Analyzing status and anomalies according to current production line usage pattern (i.e. which product configuration is being manufactured now) - behavior patterns normal for one type of production run may indicate a fault on another type of production run
4. Using data from some production cell to evaluate the reports from other, similar production cells - the cells might be in the same production line or in different production lines, allowing for quicker "learning" of more kinds of normal and abnormal behavior
5. Generating reliable problem reports for diagnosis by the consortium's diagnostics framework

Contribution to production line design:

Feedback from operating production lines can be automatically linked to specific design decisions and assist in making the new design more reliable.

Technical Approach

Scientific background

Modern statistical process control (SPC) methods assume that the faulty products are the result of independent and identically distributed error modes in the production system. Thus, various simple to apply diagnostics procedures (e.g. the control chart) are easily applicable for monitoring the quality of many types of products.

The assumption of statistical independence of events, while useful for handling the previous less ambitious quality standards (measuring faults in percents), is not useful when pushing for higher quality standards (measuring faults in parts per million). When the faults are rare, ignoring the relation between consecutive production events, eliminates the chance of tracing the faults to their cause in the production system.

The most developed statistical theory for dependence of random events, is that of Hidden Markov Models (HMM). Unfortunately, any application of that theory requires very large samples of data, which are unrealistic in the context of modern, make-for-order production systems.

Rissanen (1983) developed, within the context of data compression, an algorithm which when given a relatively short series of data, is able to identify statistical relations within the data. That algorithm is a relative of the Partial HMM (PHMM). That algorithm, while general in its nature and excellent in its compression capabilities, was never extended to handle the prediction of non-binary series, or the construction of actual models.

Project description

In the first phase of the project, the algorithm of Rissanen will be extended to nonbinary signals, a prototype software will be written, and the viability of the concept will be tested on some bench mark problems form the industry. In the second phase of the project, diagnostic procedures will be developed for specific types of industries and testing devices. The diagnostic procedures will be able to identify, based on short data samples, the relations between production conditions and product features, thus, production faults could be traced and eliminated. A modeling procedure will be developed that can match an hybrid model to a production run.

Cooperation with other CONSIST members

IET – Intelligent Electronics has extensive experience in applying expert knowledge for developing diagnostic procedures for various types of industries and processes. That knowledge will be integrated with the theoretical aspects of the research to guide it and focus it on problems of importance. The expert knowledge is essential for this type of research, specifically for mapping the faults identified to their origin in the production process, and for preprocessing the data from the production runs.

Timetables

March-September 1999: demonstration of the concept via development of prototype software and its application on some benchmark problem.

October 1999 - September 2001: Development of diagnostic procedures specifically adapted to key industries.

Annual budget requirements (US$):

Ben-Gurion University:

	Salary for Dr. Shmilovici (33%)	15,800
	Salary for research assistant (100%)	28,800
	Institution Overhead , 45% of above	20,270
	Mathematical & Statistical software	4,000
Total:		68,870

Tel-Aviv University:

	Salary for Dr. Ben-Gal (33%)	15,800
	Salary for research assistant (100%)	28,800
	Institution Overhead, 45% of above	20,270
	Mathematical & Statistical software	4,000
Total:		68,870

Budget justification:

This research has to be an intensive one if it is to produce applicable results for the given time frame. The principal investigators (Shmilovici and Ben-Gal) will handle the theoretical aspects of the research, while the research assistants (of two M. Sc. student level from TAU) will write the software implementations, gather data from actual production runs, and test the theory. Some mathematical and statistical software packages will be needed for data processing.

Short biographies

Dr. Shmilovici is from the department of Industrial Engineering and Management, in Ben-Gurion University. He specializes (among others) in fuzzy logic, developing models for complex systems, and systems identification. He published his previous work in international scientific journals and conferences.

Dr. Ben-Gal is from the department of Industrial Engineering, in Tel-Aviv university. He specializes (among others) in quality control, experiment design, and information theory. He published his previous work in international scientific journals and conferences.

Attachment B

Irad Ben-Gal

From: Oshrat Cohen [project@post.tau.ac.il]
Sent: Tuesday, May 23, 2000 10:47 AM
To: irad ben-gal
Subject: Re: Gonen Zinger

1. Yes, it means you have enough money to support them both (Gail 50% and Gonen 55%).
2. The minimum percentage for working in a consortium is 10% but the maximum for academic staff members is 33%.
That means you will loose money and I guess that something you wouldn't like...

Oshrat

irad ben-gal wrote:

> Oshrat,
> 1. Does it means that I have enough money to support him and Gail till
> the end of the period?
> 2. Can I change my own work percentage (ACHUZ MISRA) between periods?
> For example, get 10% for two months and then 43% in other two?
> Thanks,
> Irad
>
> At 07:30 AM 5/23/00 +0100, you wrote:
> >Hi again,
> >I have calculate the percentage of employment you can hire Gonen for
> >the period 6.00-12.00 and it is 55% which means 99 hours per month.
> >Please send me your letter regarding his employment.
> >
> >Thank you,
> >Oshrat
> >
> >
> >
> >--
> >
> >project@post.tau.ac.il.
> >
> >pOshrat Cohen
> >Projects Department
> >RAMOT - University Authority for Applied Research
> >   And Industrial Development Ltd.
> >P.O.B 39296
> >TEL AVIV 61392
> >
> >Phone: +972-3-6428765 ext. 445
> >FAX : +972-3-6438764 (direct), +972-3-6429865 (general)
> >E-mail: project@post.tau.ac.il (direct)
> >   ramot@post.tau.ac.il (general)
> >
> >
> >
> >

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Please pay attention that our e-mail is changed to: project@post.tau.ac.il.

pOshrat Cohen
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And Industrial Development Ltd.
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ramot@post.tau.ac.il (general)

Attachment C

Ramot of Tel Aviv University

P.O.B. 39296 Tel-Aviv 61392 Fax: 03-6429865 Tel. 03-6408113

October 11, 2000

To:
Dr. Irad Ben-Gal
Engineering Faculty

Dear Sir,

Subject: **Work Hours Report for the Research Asistants of the CONSIST Consortium**

Please provide me the work hours of the research assistants immediately, according to the following breakdown:

Name	Months to report	Position %	No. of hours to report
Gail Morag	May-September 2000	50%	90
Gonen Zinger	January 2000	50%	90
	February 2000	100%	180
	June-September 2000	56%	101

Enclosed is a report form. You should photocopy the form, and report each month separately, according to the above breakdown. Thank you for your cooperation.

Regards,

Oshrat Cohen
Project Management Dept.

Attachment D

28.7.99

Diagnostics of Production Runs Anomalies through Context Identification:
Work plan for research assistance

Gail Morag ,MSc student

- Developing SPC application from given context tree
- Model Analysis with respect to statistical errors (Type I and Type II)
- Model Analysis with respect to Bias vs. Variance
- Implementation of known statistical methods form related fields:
  - ✓ Change Point
  - ✓ Run length tests
  - ✓ SPC for non-normal distributions
- Implementing the theory in a case study, usage of Monte Carlo simulation if required ,case study

Gonen Singer , MSc student

- Construction of a q-ary context tree from a given a sequence (real numbers)
- Determining the optimal number of levels (q) by joining/splitting of tree branches, where:
  - For a large q
    - ✓ Better representation of real world
    - ✓ Less data point in each branch – lower reliability
  - For a small q
    - ✓ Abstract representations of real numbers ,operative implication derived from a particular process
- More data point in each branch – higher reliability
- Implementation of known statistical methods, such as:
  - ✓ Classification Trees
  - ✓ Minimum Entropy (Information Theory)
  - ✓ Numeric Optimization
- Implementing the theory by programming the algorithm and use of simulation

Attachment E

December 12, 1999

To:
Academic Track Division
Israel Defense Forces

Subject: Mr. Gonen Zinger

Dear Sir or Madam,

Following Gonen's request, I would like to clarify that Mr. Zinger is participating in a research project in the subject of Statistical Process Control, in the course of his studies towards a M. Sc. Gonen is actively performing the research, has achieved a number of results, and is progressing extremely well.

Regards,

Dr. Irad Ben-Gal
Industrial Engineering Departement
Tel-Aviv University

Attachment G

TEL AVIV UNIVERSITY

THE IBY AND ALADAR FLEISCHMAN FACULTY OF ENGINEERING

Department of Industrial Engineering

APPLICATION OF STATISTICAL PROCESS CONTROL TO FEEDBACK-CONTROLLED SYSTEMS VIA CONTEXT MODELING

Thesis submitted toward the degree of
Master of Science in Industrial Engineering
In Tel-Aviv University

by

Gonen Singer

This research work was carried out at Tel-Aviv University
in the Department of Industrial Engineering,
Faculty of Engineering
under the supervision of Dr. Irad Ben-Gal

June 2001

Thesis summary

During the past years, many researches develop statistical process control methods for variety industrial processes. Using this methods correctly leads to reduction in defective products, diminution in wasted resources and as a result of these effective manufacture. Traditional SPC charts, such as Shewhart, Cusum and EWMA, are based on two critical assumptions. First, there exist an a priory knowledge of the underlying distribution (often, assumed to be normally distributed). Second, the observations are i.i.d. In many industrial processes there is an inherent serial correlation between observations, thus different approaches were proposed for controlling autocorrelated process, yet the underlying principle is identical: assume that the autocorrelated process is best described by a time series model (such as ARIMA), use the model to filter the data and apply SPC schemes to the stream of residuals. The residuals are assumed i.i.d and under certain assumptions approximately Gaussian random variables, to which traditional SPC can applied.

These approaches, however, are not suitable in general to filter or model a dynamic and state-dependent data that result from feedback controlled processes. This include also SPC methods that were designed to handle correlated data, since they are based on *a priori* knowledge regarding the data distribution which may not exist, and particularly assume a time series source.

In this work we propose an alternative methodology for SPC of discrete autocorrelated string of data. The methodology is base on the context tree model, which estimates the conditional probabilities of different process outcomes given the contexts of previous observation. The context tree models the complex dynamics in the data and has several appealing characteristics: it is simple to apply; it is not based on *a priori* knowledge regarding the distribution of the generating source; it has a "learning" ability of the process dynamics and the underlying distribution; it allows convenient monitoring of discrete variables; and it enables to use a single control chart that can be further decomposed, if necessary, for analysis purposes.

In this work the Kullback-Leibler (KL) statistic is used to measure the relative 'distance' between *monitored trees* that represent the dynamics in the system at different monitoring periods, and the *reference context tree* that represents the 'in-control' behaviour of the system. Analytically and numerically we proove that these KL 'distance' statistics are i.i.d and chi-square distributed, and hence can be plotted on a simple SPC chart that consequently monitors the controlled process.

This work represents controlled hierarchic problems via optimization problem (non-linear programming). Existence of results to this problem, point on possibility of deviations between two compatible nodes in trees, while deviation between the trees themselves cannot be detect through control chart.

The context SPC method is suitable for discrete data therefore chapter six represents an algorithm for discretization of continuous data.